Least-Error Acoustic-Source Localization of Discrete Events

*David C. Torney (T-10) and Robert J. Nemzek (ISR-4); **dtorney@lanl.gov***

We developed a new method for locating a discrete acoustic source (which generates a radially-symmetric, outgoing wave) based on its times of arrival at multiple locations. This method involves optimizing the sum of the absolute values of the differences between the squares of the observed and theoretical times of arrival. The greater the number of data points, the greater the accuracy of localization, i.e., the more mitigation of the errors. Unlike the oft discovered, least-square method for this desideratum, elementary algebra (through some potentially heroic computations) suffices for our optimizations—at least when there are only two spatial dimensions.

We compared our method to a least-square method in simulations, adding noise independently to the time-of-arrival data. Figure 1 depicts results for 4–16 data points. The average prediction errors, for both methods, appear to fall off as "one over the square root of the number of data points, S," though an explanation thereof is not yet in hand.

In field experiments conducted at the Los Alamos National Laboratory Marksmanship Range, we compared the application of our method to that of an elementary method, the Time-Difference-of-Arrival (TDOA) method [1]. The TDOA method assumes no errors in the data, such as location or timing errors, hence immuring data errors as localization errors. For this method, the number of data points equals four: the smallest number sufficing, in the absence of errors, for localizing the source in two spatial dimensions and time. Figure 2 compares the performances of the TDOA method (2a) with our least-error method (2b) on the same data (four data points, at a subset of six microphones, for each of nine firings).

Note that eight of nine gun firings were located to within 3 m of their true positions by our least-error method, whereas the TDOA method was as successful with only two of nine firings. We suspect that the one firing, which was recalcitrant to our least-error method, involves a transcription error due to the data manipulations, but having all nine events amenable to our method would only have raised suspicions.
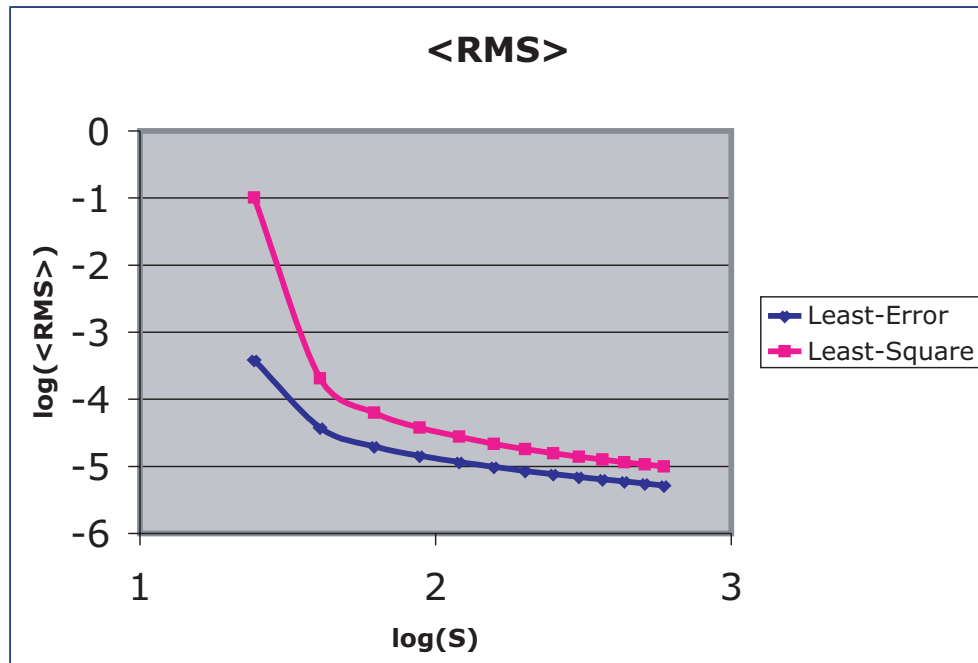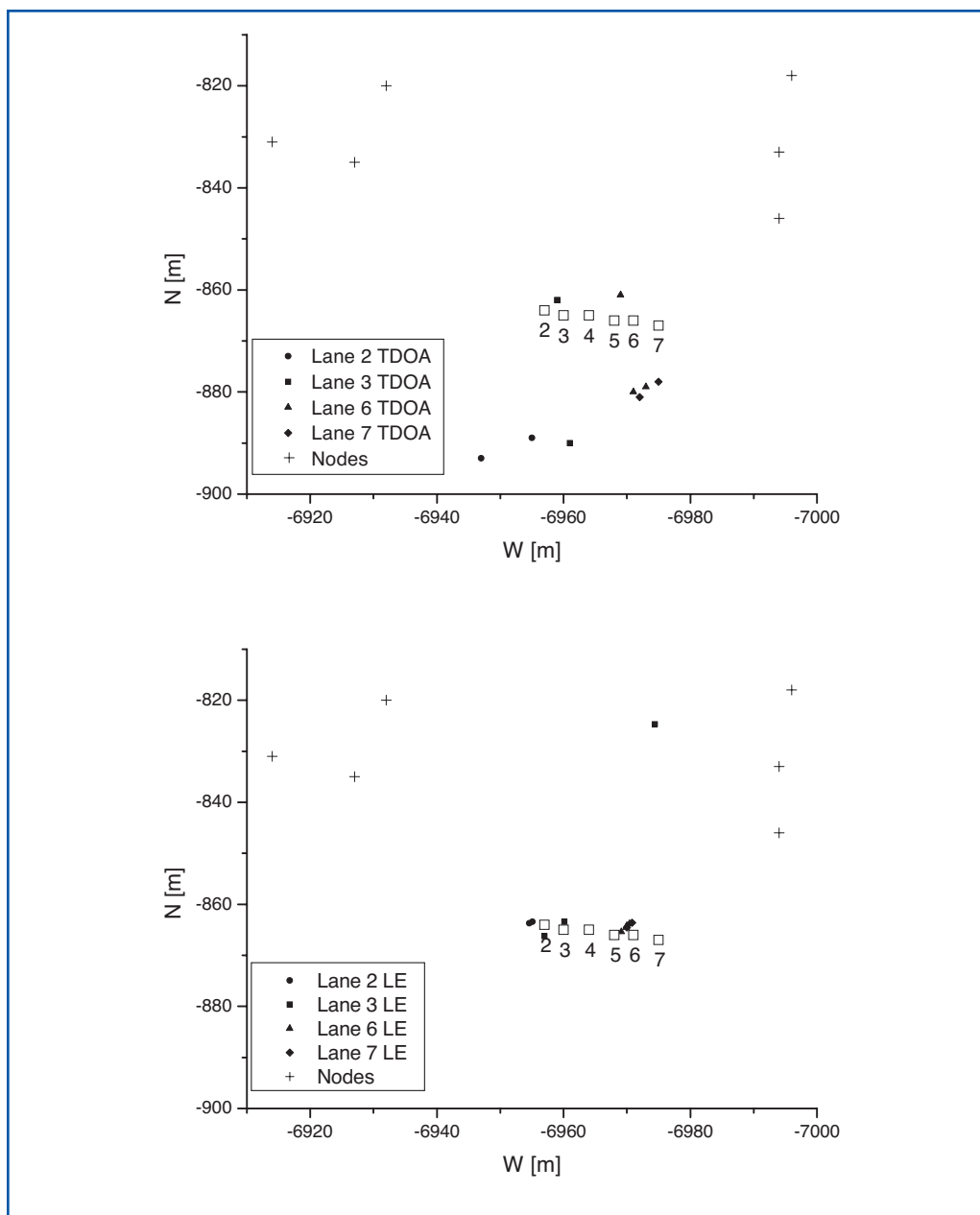
The expectation that neither bats nor dolphins are likely to echolocate by means similar to those devised by humans renders such capabilities into intrigue: the stuff of biology [2]. What are the possibilities for calculus in vivo? Such questions, howsoever alluring, remain.

[1] R.J. Nemzek and D.C. Torney, "Least-Error Acoustic-Source Localization," Los Alamos National Laboratory report LA-UR-03-5797 (2003), submitted to *Applied Acoustics*.
[2] Nobuo Suga, "Biosonar and Neural Computation in Bats," *Scientific American* **262** (June 1990), pp. 60-68.

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